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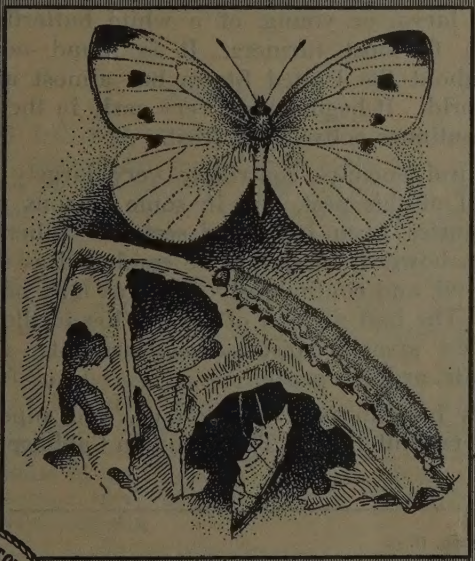
ENTOM.

THE COMMON CABBAGE WORM

AND ITS CONTROL



THE COMMON CABBAGE WORM is the best known and most important of the many insect enemies of cabbage and related crops. It feeds upon the cabbage leaves and eats into the "buds" and heads. If not restrained by natural or artificial means it would frequently cause the total destruction of the crops which it attacks, since it multiplies rapidly and produces, even in the North, three broods or generations a year.

It is a velvety green worm, or caterpillar, measuring when full grown about 1¼ inches in length, and is the larva, or young, of a white butterfly, well known to most farmers. It is found not only throughout the United States but almost all over the world. It begins work very early in the season and continues active until frost.

Natural enemies contribute very largely to the control of this pest, and in some seasons prevent its injuries from becoming serious. Wherever it occurs, however, it should be combated as soon as observed, and continuously as far as may be necessary. The best method of control lies in the use of common arsenic poisons—lead arsenate, calcium arsenate, or Paris green.

This bulletin is a revision of, and supersedes, Farmers' Bulletin 766, The Common Cabbage Worm.

Washington, D. C. May, 1926

THE COMMON CABBAGE WORM[1] AND ITS CONTROL

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INTRODUCTORY

THE MOST DESTRUCTIVE among the many insect and other enemies of cabbage and related crops is the larva, or caterpillar, of the common cabbage butterfly (figs. 1, 2). This caterpillar, the common cabbage worm, is well known to farmers throughout this country (and in the Old World as well), and the butterfly is generally recognized by the farmer as the parent of the "worms."

The common cabbage butterfly was introduced from Europe and was first recognized at Quebec, Canada, in 1860. In 1865 its first appearance in the United States was noted in Maine; in the following year in northern New Hampshire and Vermont. In 1868 it had reached New York and soon thereafter began to attract attention in other localities. In 1875 it appeared in Cleveland, Ohio, and two years later in Illinois. In 1880 it had penetrated southward to the Gulf States. The species has spread until now it is known in practically every State in the Union. It appears to favor no particular part of the country, being as destructive in the Gulf region as in Canada and New England.

DESCRIPTION

This cabbage worm is velvety green, or of about the same color as the cabbage on which it feeds. There is a faint yellow stripe down the middle of the back and a row of yellow spots along each side in line with the breathing pores. The surface of the body, viewed through a hand lens, is seen to be somewhat rough and finely

[1] *Pieris rapae* L.; order Lepidoptera, family Pieridae.

dotted with small black spots. It measures, when full grown, about 1¼ inches in length. (Fig. 1, *c*.) It differs mainly from the cabbage looper,[2] another caterpillar commonly found on such crops, in having five pairs of prolegs or prop legs (unjointed hind legs) instead of four. The cabbage looper, because of the limited number of its prop legs, "loops" in walking, like a measuring worm.

The butterfly has a wing expanse of nearly 2 inches. It is white, marked with black near the tops of the forewings. The female (fig. 1, *a*) has two conspicuous black spots on each forewing, whereas the male (fig. 2) has only one. The under side of the hind-wing is of a uniform straw-yellow color of satiny appearance, and in both sexes there is usually an indistinct black spot near its tip. The body of the female is whitish; that of the male is usually darker on the back. The male is usually smaller than the female.

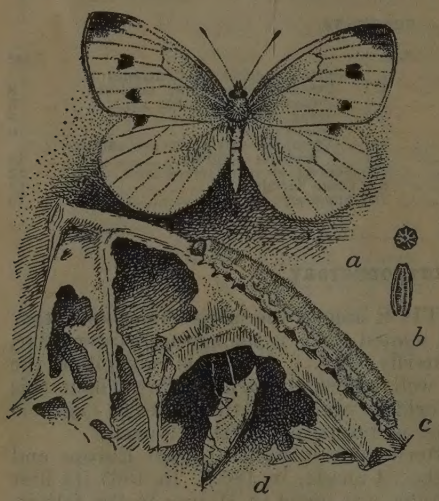

FIG. 1.—Common cabbage worm: *a*, Female butterfly; *b*, above, egg as seen from above; below, egg as seen from side; *c*, larva, or "worm," in natural position on cabbage leaf; *d*, suspended chrysalis; *a*, *c*, *d*, slightly enlarged; *b*, more enlarged

The eggs are spindle-shaped, of a pale yellowish color, strongly ribbed (fig. 1, *b*), and large enough to be seen readily with the unaided eye. They are laid by the butterfly singly, on end, and usually on the under side of the outer leaves of cabbage and other food plants.

When the caterpillar, or "worm," becomes full grown it attaches itself to a cabbage leaf or other near-by object by means of a threadlike girdle of silk, and is soon changed to a chrysalis, an inactive stage. (Fig. 1, *d*.) The chrysalis is a little less than three-fourths of an inch long, varying in color through dirty gray to yellow, green, and dark gray.

FOOD HABITS

The common cabbage worm feeds on all forms of cruciferous plants, being particularly fond of cabbage and cauliflower and less destructive to turnip, kale, collards, radish, mustard, and horseradish.

The butterflies sip the nectar of flowers of various kinds and are commonly seen hovering over them. They are especially fond of the white blossoms of crucifers, and of white aster, lavender, heliotrope, and thistle. Like other butterflies, this species is active by day, being on the wing from early morning until near dusk. It is

[2] *Autographa brassicae* Riley.

a comparatively slow but tireless flyer, capable of journeying long distances.

LIFE HISTORY

The butterflies appear on warm, sunny days as early as March, even in the Northern States, and thereafter may be seen flying until after several severe frosts in October. In the Gulf region they occur throughout the season. Pairing and egg laying begin within a day or two after the adult comes out of the chrysalis.

The different stages naturally vary in duration, depending on temperature conditions, the egg stage lasting from four to eight days.

The caterpillar, which hatches from the egg, eats greedily and grows rapidly, reaching maturity in from 10 to 14 days after hatching. It molts four times; there are therefore five distinct stages of growth, the first molt taking place, in the warmest weather, in about 2 days from the time of hatching, the second stage lasting from 2 to 3 days, the third and fourth from 1 to 2 days each, and the fifth from 4 to 5 days. In the summer time the chrysalis period lasts

FIG. 2.—Common cabbage butterfly: Male, wings spread at left, wings folded at right. Somewhat enlarged

from 7 to 12 days. In the more northerly States the insect passes the winter as a chrysalis, and the butterflies appear the following spring.

The period of development (egg to butterfly) covers between 22 and 42 days. In New England and Wisconsin this species is credited with producing three generations in a season, and five or six are reported for North Carolina.

NATURE OF INJURY

This cabbage worm has been rightly termed the bane of the cabbage grower and the dread of the housewife. It begins work early in the season, damaging young plants. After riddling the outer leaves it attacks the tender inner leaves as they form, frequently feeding within the immature heads and rendering the cabbage unfit for food because of the abundant dark-green excrement which it deposits. Before cooking it is frequently necessary to tear the head apart to insure that no disgusting worms are concealed within. In cool weather the caterpillar often feeds freely exposed on the surface of the leaves in the sunshine.

Frequently the worm works into the center of the cabbage, attacking the undeveloped "heart" and rendering the head worthless for market. (See fig. 3.) Seedling cabbage grown in cold frames is often damaged shortly after it is set in the field, the worm cutting

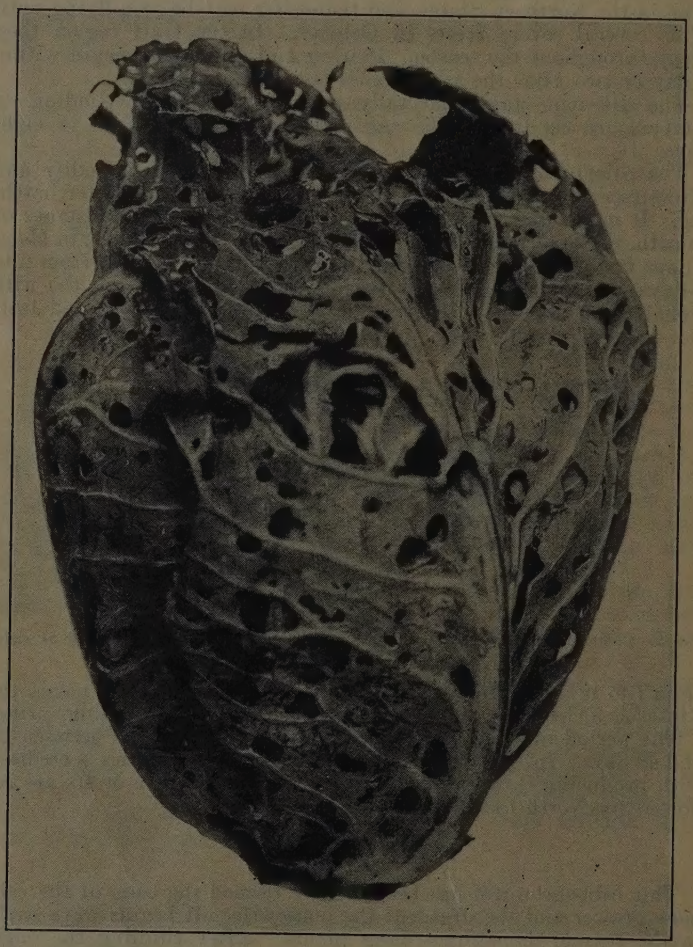

FIG. 3.—Immature cabbage head, showing injury by worms feeding within. Reduced one-half

out the "bud," and thus destroying the future head. Injury of this nature may be very serious, many plants being a complete loss. Somewhat unusually the worms occur in such numbers as to congregate on a single leaf and devour it in a very short time. (See fig. 4.)

NATURAL ENEMIES

Were it not for certain natural checks this insect would be a still greater pest. The most important of its insect enemies are small wasplike parasites, or four-winged flies, the immature forms of which feed within the body of the cabbage worm. All are introductions from Europe. One of the most efficient of these, the cabbage-worm ichneumon fly[3] (figs. 5, 6), was purposely imported in 1883 from England as a means of controlling this cabbage worm, and has more than justified its introduction. During the fall of 1904 this parasite held its host under complete control at Washington, D. C., killing every worm which came under the writer's observation. The cabbage-worm chalcis fly[4] (fig. 7) bears the same relation to the cabbage worm as does the ichneumon fly, and is therefore beneficial, especially in the Northern States. As it was first noted in this country in 1869, it was evidently imported with its host. The eggs of this chalcis fly are deposited in the cabbage worm, hatch into larvæ, and live within it, and the adult parasites which develop from them come out from the chrysalis stage of the worm.

Large wasps, particularly certain paper wasps[5] and related forms, are also of great service in reducing the numbers of this and other cabbage worms, appearing to prefer them to other prey.

The small, evil-smelling ambush bug[6] hides in flowers, such as the thistle and goldenrod, and destroys numbers of butterflies, capturing them and sucking out their body fluids.

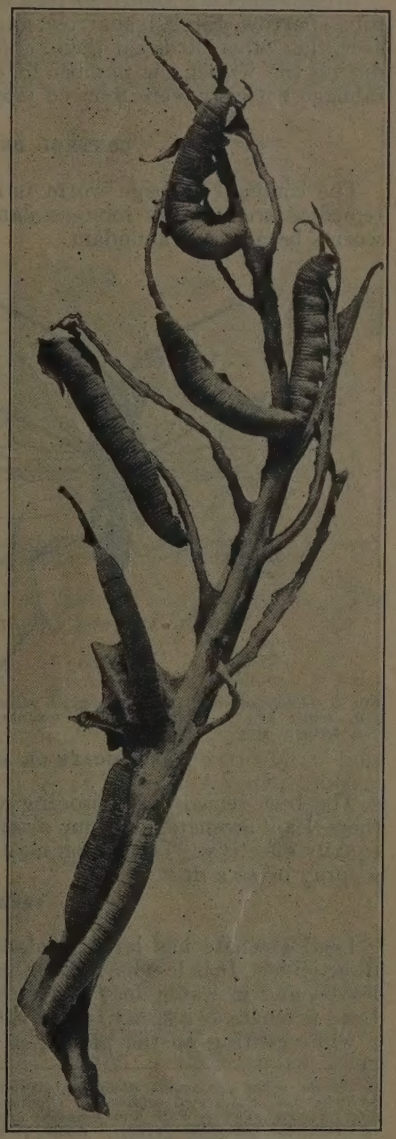

FIG. 4.—Remains of cabbage leaf eaten by seven common cabbage worms. Slightly enlarged

[3] *Apanteles glomeratus* L.
[4] *Pteromalus puparum* L.
[5] *Polistes metricus* Say, *P. pallipes* Lepel., and others.
[6] *Phymata wolffi* Stål.

Numerous other insect enemies[7] attack this cabbage worm, and it is sometimes subject to a contagious bacterial disease[8] similar to that of the cabbage looper. It is not especially susceptible to this malady, although in some seasons great numbers are destroyed by it.

Birds which are known to feed upon cabbage worms are the chipping sparrow, English sparrow, and house wren. It is certain, however, that other birds eat them, and in one case it was reported that during the winter the number of chrysalids (resting stage) of the cabbage butterfly were reduced more than 90 per cent by birds.

CONTROL ON CABBAGE

The common cabbage worm is not difficult to control if proper remedies are used as soon as damage is detected and before the worms become too abundant.

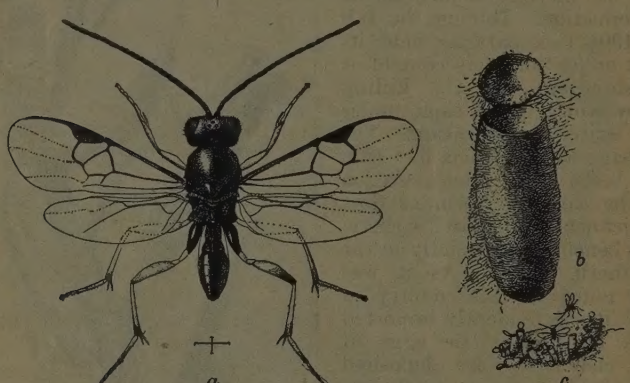

FIG. 5.—Cabbage-worm ichneumon fly, a valuable parasite of the common cabbage worm: *a*, Adult fly; *b*, cocoon; *c*, flies escaping from cocoons. *a*, *b*, highly magnified; *c*, natural size

ARSENICALS OR ARSENIC POISONS

The best remedy is poisoning with some form of arsenical; of these lead arsenate, calcium arsenate, and Paris green are about equally effective. The poison may be applied to the plants either as a spray or as a dust.

SPRAYS

Lead arsenate has largely taken the place of Paris green as an insecticide. It is less harmful to growing plants, sticks better to the leaves, and in water does not settle as quickly as does Paris green. Lead arsenate as a spray is also valuable in that it leaves, on drying, a white coating on the plants, so that after spraying it is easy to

[7] Among other predacious enemies observed in this country are the wheel bug (*Arilus cristatus* L.), the armed soldier-bug (*Podisus maculiventris* Say), the parasitic tachina flies *Exorista vulgaris* Fall. and *Frontina archippivora* Will., and a flesh fly, *Sarcophaga* (*Boettcheria*) *latisterna* Parker. About 10 additional parasites are listed in Europe.

[8] *Micrococcus pieridis* Burrill.

see which plants have been treated and how thorough the treatment has been. The spray should be mixed as follows:

Lead arsenate (powder)	2 pounds	or	½ pound.
Soap	2 pounds		½ pound.
Water or Bordeaux mixture	50 gallons		12½ gallons.

Calcium arsenate has a higher arsenic content than lead arsenate and therefore possesses greater killing power. Its adhesiveness is about the same as that of lead arsenate. The spray should be mixed as follows:

Calcium arsenate (powder)	1½ pounds	or	6 ounces.
Soap	2 pounds		8 ounces.
Water or Bordeaux mixture	50 gallons		12½ gallons.

For small amounts of sprays use 10 level teaspoonfuls of the arsenical to 1 gallon of water and about 1¼ ounces of soap.

Paris green was one of the first poisons used for the control of leaf-feeding insects. The objections to its use are that it is likely to injure foliage, it does not remain mixed with water for any length of time, and does not stick well to leaves such as those of cabbage and cauliflower. The spray should be mixed in the following proportions:

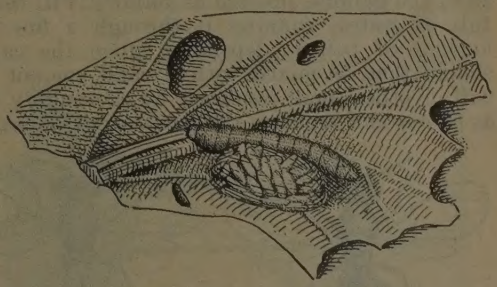

FIG. 6.—Parasitized cabbage worm, showing cocoon mass of cabbage-worm ichneumon fly below

Paris green	1 pound	or	4 ounces.
Soap	2 pounds		8 ounces.
Water or Bordeaux mixture	50 gallons		12½ gallons.

The sticking and spreading qualities of these spray materials are improved by the addition of soap, which is particularly valuable in sprays to be used on such types of leaves as those of cabbage. Effective treatment requires about 150 gallons of spray to the acre for one application. When applied with a hand sprayer about 1 gallon of the spray to 50 feet of row will be required.

DUSTS

Arsenic poisons may be applied in dust form by mixing the poison with a cheap carrier, such as hydrated or air-slaked lime, land plaster, dusting sulphur, or other cheap, light, finely pulverized material, which will adhere to the cabbage leaves.

Dusts are more easily and quickly applied than sprays, but do not always distribute the poison so evenly. Unless applied when the foliage is wet, the dust does not stick so well as does a spray mixture.

The following mixtures are recommended:

Lead arsenate	1 pound.
Hydrated lime	5 pounds.
Or	
Calcium arsenate	1 pound.
Hydrated lime	5 pounds.
Or	
Paris green	1 pound.
Hydrated lime	15 pounds.

The dusts should be applied at the rate of about 30 to 40 pounds to the acre.

PREPARATION OF SPRAY MIXTURES

When preparing the spray mixtures in quantities, such as from 25 to 100 gallons, proceed as follows: Fill the spray tank about half full of water, running it through a fine strainer. The proper amount of poison, depending upon the capacity of the sprayer, should then be mixed with a small amount of water in a 3-gallon pail or other small container by thoroughly stirring the mixture so as to wet and separate the particles of poison. Then pour this concentrated mixture through a strainer into the spray tank and add the full amount of water to the sprayer. The soap should be dissolved in small quantities of hot water before it is added to the spray. It is good practice to prepare the soap solution some time before spraying is to begin, so that the time consumed in dissolving the soap will not cause any unnecessary delay in the spray work.

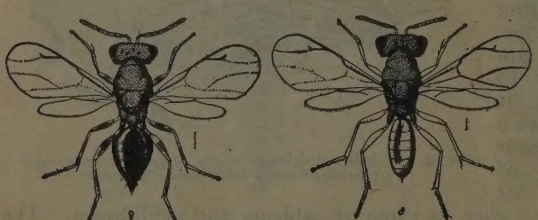

FIG. 7.—Cabbage-worm chalcis fly, a useful parasite of the common cabbage worm. Female at left, male at right. Size shown by hair line at right

In preparing small quantities of spray mixtures the poison should be first mixed with a little water and thoroughly stirred before the full amount of water is added. Unless the spray is kept fairly well agitated or stirred, the poison will separate from the water and settle to the bottom of the tank. It is therefore necessary, in order to keep the spray mixture uniform, that the sprayer be equipped with a good agitator or some means be taken to stir the spray mixture from time to time. In the case of hand compressed-air sprayers, these can be shaken vigorously at intervals and a wooden paddle can be used to keep the spray mixture stirred in bucket pumps not equipped with agitators.

PREPARATION OF DUSTS

In the preparation of poisoned dust mixtures the principal object is to mix the poison thoroughly with the material which is used to dilute the poison, such as hydrated lime, land plaster, etc. A satis-

factory mixture can be prepared in 50 to 100 pound lots by placing the materials in a steel drum or barrel which can be tightly closed and then rolling the drum for a distance of 400 to 500 feet. At intervals of about 50 feet the drum should be turned end over end a few times. Another method, which can be employed when a steel drum is not available, is to mix the dust in a flat box with a garden hoe. The lime or other substance which is to be used to dilute the poison should be spread out in a thin layer over the bottom of the box and about one-fourth of the poison should be evenly distributed over this layer and the two materials mixed thoroughly with the hoe. The dust should then be drawn up in a pile to the center of the box, care being exercised to remove it from the corners. This mixture should then be spread out in a thin layer, another fourth of the poison added, and the mixing process repeated. This procedure should be continued until all the poison is mixed with the material which is used to dilute it. Any poison mixtures which remain

FIG. 8.—Wheelbarrow type of sprayer; effective for moderate-sized areas

unused after dusting operations should be plainly marked "Poison" and stored until needed.

SPRAY EQUIPMENT

For the application of sprays, machines that will develop a high pressure are the most satisfactory. Where large acreages are to be treated, the arsenicals may be applied by power or traction sprayers. In power sprayers the pump is usually operated by a gas engine, and in traction sprayers the pump is operated from a wheel of the spray cart. The spray should be applied to each row of plants by three nozzles, one directed downward and one to each side of the row.

For smaller plantings a barrel or wheelbarrow type of sprayer will be found satisfactory. (See fig. 8.) In small garden patches a hand sprayer of the compressed-air type (fig. 9) does effective work.

The nozzles used should be of the type which delivers a cone-shaped spray. Under pressure this type of nozzle gives a fine, mist-like spray, very desirable for effective results.

DUSTERS

Power or traction dusters (fig. 10) are most useful for large plantings. Hand dusters (fig. 11) may be used with success on one or two acres.

FIG. 9.—Compressed-air sprayer in operation. Note method of carrying. Right hand controls outlet valve

Dust may be applied to garden plantings by means of a cheese-cloth sack (fig. 12) shaken over the plant, or by means of a tin can with holes punched in the bottom of it the size of a 10-penny nail, and a stick for a handle attached to its side. The dust is applied by shaking the can over the plant. Treatment by these methods is

FIG. 10.—Traction type of duster in operation in cabbage field

FIG. 11.—Dusting cabbage field. Note cloud of dust completely covering all parts of plants

not so effective as that obtained by the use of machinery made for dusting purposes.

ARSENICALS SAFE TO USE ON CABBAGE IF PROPERLY APPLIED

Arsenicals can be applied with safety until the heads of the cabbages are nearly formed, as the poison disappears almost completely within two or three weeks after application, and even earlier if there are frequent rains. Arsenic should not be applied just before the cabbage is cut or if the worms have tunnelled into the mature head. After the removal of the outer leaves, in preparing cabbage for market, and after other useless leaves have been picked off, as is done before the cabbage is cooked or prepared for salad, usually very little, if any, arsenic is left.

FIG. 12.—Dusting cabbage with cheesecloth bag

Chemical analysis has shown that a week after cabbage had been sprayed with an arsenic poison as prescribed in this bulletin, and prepared for cooking in the usual manner—that is, by removing all loose outer leaves—not a trace of arsenic remained. The writer knows of no authentic recorded instances of poisoning from the consumption of cabbage treated with an arsenical poison. It is not recommended that arsenical poisons be used on cabbage in cases where the outer leaves are to be used for human food as "greens," or are to be fed to livestock.

CONTROL ON OTHER CROPS

Arsenical treatment, as recommended for the control of the worm on cabbage, can be employed to protect seedling crops of cauliflower, Brussels sprouts, collards, turnips, kale, and mustard. In the treatment of cauliflower and Brussels sprouts arsenicals can be applied with safety until the edible heads of the cauliflower or the "sprouts" of the Brussels sprouts appear, but after this period in the development of the plant the use of arsenical poisons *should be avoided*, as the edible portions of the plant are likely to retain some of the poison at harvest. Turnips, kale, and similar plants which bear edible foliage should receive applications of the poison only in the seedling stage of the crop.

CLEAN FARMING

If by any possibility cooperation in clean methods of farming and in the use of arsenicals could be obtained, much of the loss due to the cabbage worms might be averted. The practice of leaving cabbage

stalks and heads and remnants unfit for market in the field after the main crop has been harvested should be avoided. All remnants should be disked or plowed under.

SUMMARY

The common cabbage worm is a velvety green caterpillar, about 1¼ inches long when full grown. It is the larva or young of a white butterfly. It begins work on young plants soon after they are set out, and will, if unmolested, riddle the outer leaves and eat into the "buds" and heads. As a result of its activities entire crops are sometimes seriously damaged.

It is a serious menace to the cultivation of cabbage, cauliflower, turnip, and related crops, and the farmer must be prepared to combat it during their growth. In the warmest weather it can develop from egg to adult, or butterfly, in a minimum of 22 days. Even in its northernmost range it develops three generations, or broods, annually, and southward there may be as many as six distinct generations.

Natural enemies contribute largely to the control of this insect. Without them it would be still more destructive. It is necessary, however, to resort to insecticides for satisfactory control, the most useful being lead arsenate, calcium arsenate, and Paris green, applied either as sprays or dusts. The method of application can be varied according to the area to be treated. If properly applied arsenical poisons can be safely used for this purpose.

Cooperation in clean methods of farming, if it could be brought about, would do much to avert the ravages of the cabbage worm.

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December 30, 1925

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FARMERS' BULLETIN No. 1462

ENT.

THE POTATO LEAFHOPPER

AND HOW TO CONTROL IT

THE POTATO LEAFHOPPER is a very small green insect which often occurs in vast numbers. It is a serious and costly enemy of potatoes, beans, and other crops in the North-Central and Northeastern States.

It injures potatoes by feeding on the foliage, and causes a diseased condition called hopperburn, which, under conditions favorable to its spread, may ruin an entire crop in one or two weeks.

This leafhopper can be controlled and the hopperburn held in check by the proper and timely application of Bordeaux mixture. Yields are greatly increased when this spray is used.

This bulletin has been prepared to acquaint the grower with the insect, the nature of its injury to vegetable crops, and the proper measures for its control. It is a revision of and supersedes Farmers' Bulletin 1225, The Potato Leafhopper and Its Control.

Washington, D. C. May, 1926

THE POTATO LEAFHOPPER AND HOW TO CONTROL IT

By J. E. Dudley, Jr., *Entomologist, Truck-Crop Insect Investigations, Bureau of Entomology*

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THE POTATO LEAFHOPPER[1] is one of the most important insect enemies of the potato in the United States. Serious outbreaks have occurred periodically in certain sections since the early eighties, and about 1896 this insect became known as a menace to the potato crop in the Middle and Eastern States. This leafhopper attacks a large variety of plants and may at times become injurious on several of them.

The feeding injury, although severe, is not nearly so serious as the diseased condition called "hopperburn," which appears on the plants on which the leafhopper feeds.

It is necessary to recognize this leafhopper in order to be prepared to control it and to prevent the loss of large acreages of potatoes from hopperburn.

FIG. 1.—Adult potato leafhopper. Greatly enlarged

DESCRIPTION

The adult or full-grown leafhopper (fig. 1 and fig. 2, G) is a very small, pale-green insect, about one-eighth of an inch long, with prominent white markings. It has a more or less distinct H on its body between the head and base of the wings. There

[1] *Empoasca mali* LeB., order Hemiptera, family Cicadellidae.

51156°—26

are six roundish white spots above this H and three white, wedge-shaped spots below it. Adults fly and hop readily when disturbed.

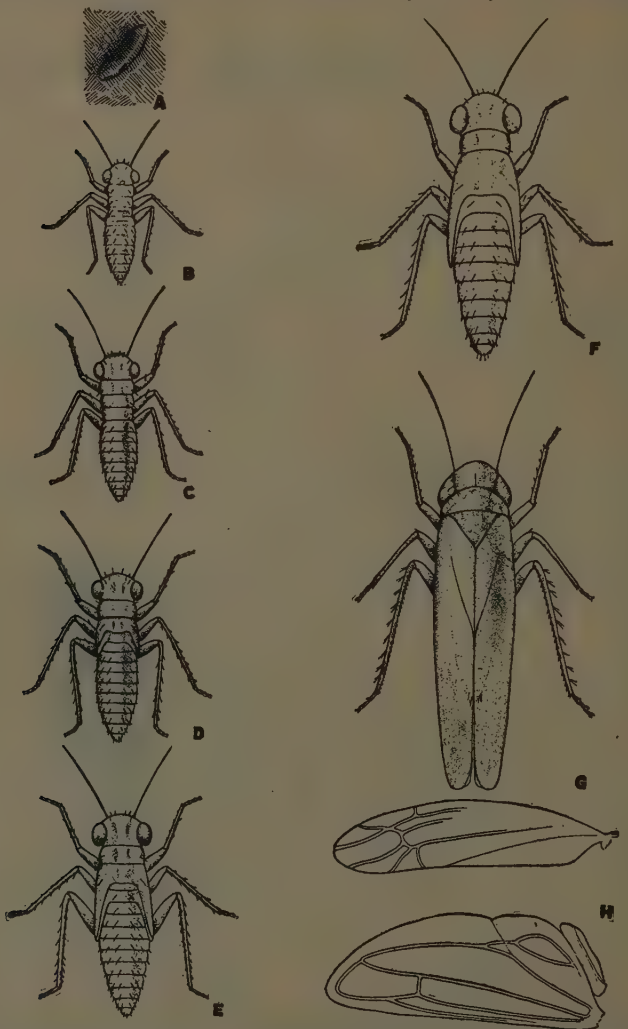

FIG. 2.—Stages in the growth of the potato leafhopper: A, Egg in tissue of leaf; B–F, stages of young leafhopper or nymph; G, adult leafhopper; H, fore and hind wings of adult leafhopper

The eggs (fig. 2, A) are tiny and transparent. They are laid in the tissue of the potato leaf and are invisible from the outside, but after they hatch the leaf tissue dies and forms small, sunken pits marking the previous location of the eggs.

The nymphs (fig. 2, B to F), or young leafhoppers, pass through five stages of growth and shed their skins each time, developing wings in the adult stage. When newly hatched, the nymphs are very small and nearly white, but slowly turn green as they grow. When the insect is nearly mature, the partially developed wings may be seen on each side of the body. At this stage the nymph is very active, being able to hop from leaf to leaf.

DISTRIBUTION

The potato leafhopper occurs in practically every State of the Union, in parts of Canada and Mexico, and in South America. Its greatest damage to potatoes has occurred in the Northern and Central States, roughly from Montana to New York, and south to Ohio, Illinois, and Kansas.

ECONOMIC IMPORTANCE

The economic loss to the potato grower caused by the attack of the potato leafhopper and the accompanying hopperburn is probably greater than that caused by any other potato insect. The loss caused by its attack on certain other crops, notably beans, is considerable. As the insect appears in injurious numbers periodically and as injury caused by it may spread very rapidly under favorable weather conditions, it is essential that the grower be equipped and ready to cope with an outbreak before it has threatened his crop.

SEASONAL HISTORY

The potato leafhopper lives over the winter in the adult stage, hidden away in brush heaps, matted dead vegetation such as weeds, and other protected places. From May 1 to 15, according to the season, leafhoppers emerge from their winter quarters, feed for a week or so on various trees and shrubs, then migrate suddenly to potatoes and beans, where mating and egg laying begin. This definite migration usually takes place the first week in June. Adults of the first generation, appearing the last of July and the beginning of August, migrate to some extent from early to late potatoes. The time and extent of this migration are determined by the temperature and the condition of the vines upon which they have bred. In this way late-planted potatoes become infested. There are two generations of the insect each year in the Northern States.

Under conditions in Wisconsin the adults which have lived through the winter die off in July and their young mature about the last of July, forming the first generation. Thus it takes approximately one month from the time the eggs are laid until the adult leafhoppers appear. A second generation is now produced, although in a slightly longer time, and the new adults begin to appear early in September. These adults live through the winter and do not lay eggs until the next spring.

HOPPERBURN

Adults and nymphs of the potato leafhopper suck the juices or sap of plants by means of their delicate beaks, which they insert into

the leaves. The injury thus caused through loss of plant juices must of itself be considerable when a large number of leafhoppers are present.

In addition to the injury caused by loss of plant juices, however, this leafhopper is the cause of a distinct injury called "hopperburn," which follows its feeding on potato and many other plants (fig. 3).

The first symptoms of hopperburn are a slight yellowing, usually of the tip of a leaflet. As the disease progresses, the leaflet slowly turns brown, curls upward, and dies. The diseased condition spreads from the tip or margin toward the midrib of the leaflet, but spreads more slowly toward the base, and the basal area of leaves may remain green until the whole plant is nearly dead.

FIG. 3.—Potato leaf affected with hopperburn. Upper surface of leaf, showing typical upcurled brown tip and margin

During periods of hot, dry weather leafhoppers reproduce very rapidly; the females are stimulated to lay eggs faster and the nymphs develop in a shorter time. Thus, with a constantly increasing population, hopperburn spreads very rapidly. The effect of hopperburn combined with the effect of dry weather may kill whole fields of early potatoes in a week's time (fig. 4). On the other hand, during cool, moist weather, which slows down the increase of leafhoppers, and especially where protective sprays have been applied, the disease is checked, and throughout the summer it may progress no farther than the primary symptoms (fig. 5).

Observations made in Wisconsin have shown that whenever leafhoppers were present in potato fields hopperburn could be found, and that when no leafhoppers were present no hopperburn could be found. In other words, the leafhoppers and hopperburn are always found together.

HOW HOPPERBURN AFFECTS DIFFERENT VARIETIES

Leafhoppers placed on Early Triumph potato plants growing in a field and covered with a large cage caused hopperburn, which killed the plants in 23 days (fig. 6, A and B). Leafhoppers placed

FIG. 4.—Early Ohio potatoes killed by hopperburn. Great abundance of leafhoppers and a period of hot, dry, July weather caused these potatoes to succumb to hopperburn in a short time

FIG. 5.—Main-crop potatoes protected from hopperburn by Bordeaux mixture. Two sprayings with Bordeaux mixture kept this field fairly free from hopperburn

on Early Ohio plants under the same conditions caused hopperburn, which killed the plants in about 40 days. Similarly, hopperburn killed Irish Cobbler plants in about 55 days and Rural New Yorker plants in about 50 days. Green Mountain potatoes under like con-

FIG. 6.—Presence of many leafhoppers means hopperburn. Triumph potatoes growing in field, covered with large cage containing leafhoppers for entire season. *A*, Condition of plants on August 14; B, condition of same plants when dug on September 2. Compare with Figure 7

ditions became badly diseased, but were still alive two months after the leafhoppers were placed on them.

Plants of all the foregoing varieties which were confined and kept free of leafhoppers showed no symptoms of hopperburn during a period of two months (fig. 7, A and B).

Observations made in several potato-growing sections of Wisconsin have shown that the Triumph variety is invariably more severely affected with hopperburn than any other variety grown commercially in that State. Usually the Rural New Yorker has been found to be the most resistant to hopperburn of any variety grown commercially in Wisconsin.

FIG. 7.—Absence of leafhoppers means no hopperburn. Triumph potatoes growing in field, covered with large cage for entire season and kept free of leafhoppers. A, Condition of plants on August 14; B, condition of same plants when dug on September 2. Compare with Figure 6

FOOD PLANTS

The potato leafhopper visits a considerable number of plants for feeding purposes. The more important economic plants on which reproduction takes place and hopperburn occurs are the following: Potato, beans (practically all varieties), sugar beet, hemp, apple, and raspberry. It also attacks several ornamental trees and shrubs. Reproduction appears to take place most readily on potato, with beans as a second choice. Hemp, sugar beets, and apple nursery stock are more liable to severe injury when growing near potato or bean fields.

String, pole, and navy beans are at times severely injured by hopperburn, and if the plants are not killed outright the yields are greatly reduced. Lima beans and soybeans are not so heavily attacked, nor is hopperburn ever severe on them; this is the case in Wisconsin, at least.

Not only are certain varieties of potatoes less severely affected with hopperburn than are others, but some plants of any one variety are found to be more resistant to hopperburn than are other plants of the same variety.

NATURAL ENEMIES

Although there are three known natural enemies of the potato leafhopper, none has become important as a control. One, a tiny insect parasite, breeds in the leafhopper eggs, but does not occur in sufficient numbers to reduce noticeably the number of leafhoppers.

A fungous disease attacks both adults and nymphs, or young. Leafhoppers affected with fungus[2] soon die and turn from green to yellowish in color. In a short time a heavy fungous growth, having colors of the rainbow, appears on the insect's body (fig. 8). Warm, moist weather is necessary for the growth and spread of this fungus. In 1919 it was common all over Wisconsin, and in certain localities practically exterminated the leafhoppers. In 1920, however, not a single specimen of the fungus was found. From 1920 to 1923 it has occurred sporadically, but has not been a factor in control. Spiders often prey on both adults and nymphs, or young.

CONTROL OF THE LEAFHOPPER AND PREVENTION OF HOPPERBURN

The results of six years' experiments show that Bordeaux mixture controls the leafhopper, killing many of the nymphs, or young, and repelling the adults. It is the best-known remedy for the prevention of hopperburn.

Bordeaux mixture combined with nicotine sulphate acts a little more quickly in ridding plants of leafhoppers than does Bordeaux alone, but the results obtained do not appear to justify the added time and expense of using the nicotine.

Nicotine sulphate combined with soap has been found very effective in killing nymphs, or young, and the few adults present at the time when the spray was applied. There was no lasting effect, however, because leafhoppers reappeared in a few days. Hopperburn was not controlled.

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[2] *Entomophthora sphaerosperma.*

Kerosene emulsion acted in the same way as nicotine and soap, killing the leafhoppers which it hit, but having no lasting effect.

ACTION OF BORDEAUX MIXTURE

Bordeaux mixture properly applied to plants will kill nymphs, repel adults, and keep the plants free from them as long as a good coating of spray is kept on the foliage. Unsprayed plants growing next to properly sprayed plants, or even among them, will be heavily attacked by leafhoppers and become badly affected with hopperburn.

FIG. 8.—Fungous disease that checks leafhoppers. The fungus has a rainbowlike appearance after covering the body of the insect

The effect of Bordeaux mixture on hopperburn varies with different varieties. Rural New Yorker potato plants well sprayed have remained almost free of hopperburn until digging time. Triumph potatoes, on the other hand, while they were prevented from becoming badly diseased until after tubers had well developed, were affected much more by hopperburn than any other variety tested. Unsprayed Triumph plants died from the effects of hopperburn before the middle of the season. The five types of potatoes used, in order of their susceptibility to leafhopper attack and to hopperburn, were: Triumph, Irish Cobbler, Early Ohio, Green Mountain, and Rural New Yorker.

HOW TO PREPARE BORDEAUX MIXTURE

The ingredients and method of preparation of Bordeaux mixture are as follows:

Copper sulphate (bluestone)	pounds	4
Quicklime	do	4
Water to make	gallons	50

Prepare the copper sulphate or bluestone by suspending it in a gunny sack just below the surface of several gallons of water in a clean barrel. When the bluestone is dissolved, which requires three or four hours, remove the sack and stir into the barrel enough additional water to make exactly 25 gallons of the copper solution.

As the use of quicklime on the farm entails more or less trouble in storing and preparing, many growers are using hydrated lime instead. If it is fresh and of good quality, very good results may be obtained with it. It is easy to keep and to mix, and is usually easy to obtain. Six pounds of it should be used instead of the 4 pounds of quicklime. It should be mixed directly with enough water to make exactly 25 gallons.

If quicklime is used, slake it slowly and thoroughly in a small container, strain into a barrel, and add enough additional water to make exactly 25 gallons of lime milk.

Pour the two ingredients together into another barrel or, better, directly into the spray tank, if it will hold 50 gallons. It is highly important to stir the mixture very thoroughly and to strain both ingredients before they are combined, as otherwise clogging of the spray nozzles may result. Use copper or bronze wire strainer of 18 meshes to the inch. Do not put copper sulphate or Bordeaux mixture into tin or iron vessels; use wood or copper containers. Mix the Bordeaux solution as needed and apply at once. It is never so good after it has settled.

To prepare Bordeaux mixture in small quantities use 1 pound of bluestone, 1 pound of stone lime, or 1½ pounds of hydrated lime, and 12½ gallons of water, and proceed according to the directions just given for preparing 50 gallons of Bordeaux mixture, with the exception that smaller containers can be used.

STOCK SOLUTIONS

Everyone who uses Bordeaux mixture frequently and in quantity will find it convenient to keep on hand concentrated stock preparations of copper-sulphate solution and milk of lime in separate containers. These stock preparations keep indefinitely if the water which evaporates is replaced.

Build an elevated platform to hold the barrels. Some time before the day on which it is desired to commence spraying put 50 pounds of bluestone in a sack and hang it in a barrel with 50 gallons of water, to dissolve. Slake 50 pounds of quicklime, or mix 75 pounds of hydrated lime, in another barrel and add water to make 50 gallons of lime milk. When Bordeaux mixture is needed, stir both stock barrels and take from each as many gallons as the formula calls for in pounds. Dilute the copper sulphate in one barrel and the lime milk in another, each with half the water to be added, and let the two run together into the strainer of the spray tank. Thorough agitation is important in making a good Bordeaux mixture.

HOW AND WHEN TO APPLY BORDEAUX MIXTURE

To control the potato leafhopper, Bordeaux mixture *must* be applied to the under side of the leaves, and spraying must be done thoroughly, in order to cover practically all of the foliage. Each side of every row of plants must be sprayed (fig. 9).

A high pressure (at least 150 pounds) should be maintained in order to cover the leaves with a fine mist, which gives a much better coating than does a coarse spray (fig. 10).

In years when leafhoppers are abundant at least three applications of Bordeaux mixture should be made, the first as soon as the leafhoppers have appeared on the plants. Where necessary to con-

FIG. 9.—Spraying potatoes properly. A high pressure is needed, and three nozzles should be used for each row, the outer two directing the spray upward and inward. In experiments carefully performed, four such sprayings increased the yield of potatoes 44½ per cent over the yield obtained when two nozzles per row were used, directing the spray downward

trol the Colorado potato beetle, add 1 pound of powdered arsenate of lead to each 25 gallons of the Bordeaux mixture. The second spray should be applied from 10 days to 2 weeks later, depending upon the amount of spray remaining on the plants and the amount of new growth. A third, and even a fourth, spray may be necessary in very hot, dry summers or in years when leafhoppers occur in vast numbers, but the time when these extra applications should be made must be determined by examinations of each field.

As Bordeaux mixture is used for several purposes on potatoes—to repel flea beetles and control certain plant diseases—it is most fortunate that it has been found to be a control for leafhoppers and hopperburn, and it may fit nicely into the regular spraying schedule.

FIG. 10.—The wheelbarrow sprayer is effective for small patches. The boom carries two nozzles

SUMMARY OF CONTROL MEASURES

Spraying with Bordeaux mixture appears to be the only practical method of control for the potato leafhopper and for preventing the appearance or spread of hopperburn.

The 4–4–50 formula is generally used.

It should be thoroughly applied to the *under side* of the leaves, at least 150 pounds pressure being used, so that a fine mist spray will result.

Make at least three applications, and spray a fourth time if necessary to keep down hopperburn until the crop has matured.

To make the application thorough, spray both sides of each row.

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